National Aeronautics and
Space Administration

Instrumentation

Highly Accurate Position Detection and Shape Sensing with Fiber Optics

Novel method for determining position, shape, and curvature

NASA's Langley Research Center has demonstrated a patent pending method and apparatus for determining the position, in three dimensions, of any point on an optical fiber. The new method uses low reflectance Fiber Bragg Grating (FBG) strain sensors in a multi-core fiber to determine how any point along that fiber is positioned in space. The characteristics of optical fibers and the FBGs vary with curvature, and by sensing the relative change of FBGs in each of three or more fiber cores, the three-dimensional change in position can be determined. By using this method in monitoring applications where optical fibers can be deployed--such as in structures, medical devices, or robotics--precise deflection, end position, and location can be determined in near real time. This innovative position detection method offers 10 times greater positional accuracy than comparable optical techniques.

BENEFITS

- Accuracy is improved for measuring position changes and complex shapes
- Allows position and shape visualization of embedded or hidden fiber optics
- Positional accuracy (less than 1mm) is 10x better than comparable fiber-based techniques
- Provides high spatial resolution for fibers up to 10 meters in length
- Novel algorithm avoids the accumulation of errors due to fiber twisting, thermal gradients, and other error sources
- Can be extended to other forms of cable

technology solution

THE TECHNOLOGY

NASA's novel method was developed to more accurately measure the position and shape of optical fibers. Multi-core optical fibers contain multiple light-guiding cores arranged symmetrically. Sensors, such as FBGs, are embedded into each of the cores (Figure 1). Such an arrangement allows for the measurement of strain in each core of the fiber at specific axial locations along the fiber. When a multi-core fiber is subjected to bending, the strain imposed in each core relative to one another is used to provide position information (Figure 2).

In the past, shape-sensing measurements using optical fibers estimated bending at sequential points along the fiber, and the resulting measurement had many discontinuities and errors. The combination of these errors resulted in a very poor indication of actual fiber position in three-dimensional space.

NASA's patent-pending algorithms and apparatus incorporate not only fiber bending measurements, but fiber twisting measurements as well, to eliminate previous sources of error. The uniqueness of the algorithm is in how the curvature, bend-direction, and twisting information of the fiber are all brought together to obtain a highly accurate 3-D location and shape characterization. The new methods have been demonstrated to significantly improve the accuracy of multi-core fiber optic shape sensors.

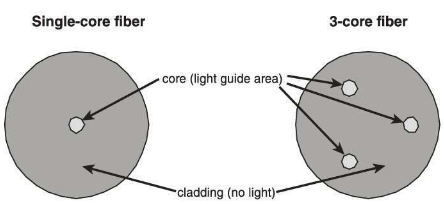

FIGURE 1 - Axial views of single-core and multi-core fiber

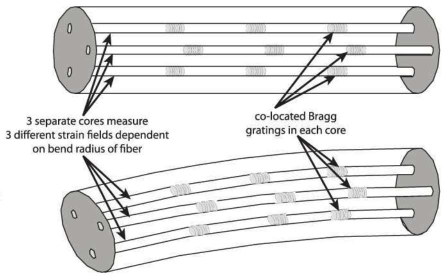

FIGURE 2 - Bend measurements in multicore fiber with fiber Bragg gratings

APPLICATIONS

The technology has several potential applications:

- Aerospace safety - aircraft and spacecraft integrated vehicle health management systems
- Medical - minimally invasive surgical devices; end-effector tracking
- Cabled remote vehicle - robot position tracking for collapsed buildings or mineshaft search and rescue
- Space exploration - tethered instrument position tracking

PUBLICATIONS

Patent No: 7,813,599; 8,746,076

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